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II. *The Croonian Lecture on Muscular Motion.*

By George Fordyce, M. D. F. R. S.

Read November 22, 1787.

THE subject of muscular motion has been so often considered, and in so many lights, that it is hardly possible to avoid many observations which are trite, and even puerile; which, when they occur, I beg the learned Society to forgive. They will also find so little new, or even nothing, that I should be inexcusable in taking up their time, if the subject was not annually to be discussed before them. In considering muscular motion, I must begin with some observations on motion in general, and with that well known, and self-evident axiom, that one particle of matter, considered by itself, will remain at rest if it be at rest, and will continue in motion if it be in motion, and in the same direction. This has been called the *vis insita*, or *vis inertiae*, of matter. It may be said in other words, that a single particle of matter being at rest, would therefore always continue at rest, if it were not for some external impulse made on it. This impulse may be from some other particle of matter in motion impinging upon it, and communicating part of its motion to it, while it communicates an equal quantity of its rest to the matter so impinging upon it, so that the quantity of motion and rest shall be the same after the impinging, in both bodies, as they were before: or, in other words, a simple particle of matter in motion would always
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continue in motion, in the same direction, if it did not meet with another, on which it impinged; and after the impinging, there would be the same quantity of motion and rest in both bodies taken together, as was before. If we consider equal motion, in direct contrary direction, as rest; motion, or rest, produced in a body by the above means, I shall call communicated.

If two simple particles of matter, of any species, not farther distant from one another than the sun is from the earth, were both at perfect rest, these two particles would instantly begin to move toward one another, if no other particle of matter whatever existed.

I do not mean to tire my learned Audience with demonstration of propositions so well known.

There would, therefore, be an impulse, producing motion between these bodies, without any contact.

Motions produced in this way, I call original motions.

The first consideration with regard to any particular motion is, therefore, whether it be an original or communicated motion. If it be an original motion, it will follow the laws of that particular species of original motion; if it be a communicated motion, it will follow the laws of communicated motion.

Many observations shew, that muscular motion is not a communicated motion, and therefore an original one.

In any system of bodies, or particles of matter, affecting one another only by the motions already existing in them being communicated to one another, they may diminish their motion, or bring one another to rest; but they never can increase the motion existing in the whole. It happens frequently, that the motions in the animal body are increased, without any alteration of external applications to it; the cases are so numerous, that it is hardly worth bringing an example: we might
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mention the increase at times of the circulation, and all the motions of the fluids without the least new motion in the surrounding bodies, or interference, or even knowledge of the mind. This motion must therefore be original, and not communicated.

In communicated motion, if one body be at rest, and a motion be communicated to it by another, the power of the whole motion shall not be greater than that in the communicating body at the time of the communication. If I take out the heart of an animal, cut off the auricles, it will in many cases continue to contract and dilate for some time. If it be left to come to rest, and if soon after a needle be introduced into the ventricle, placed transversely, and if the interior surface of the ventricle be pricked gently by the needle, the ventricle will contract with such power as to force the needle deep into it: in this case, the force of the contraction of the ventricle is much greater than the power with which it was pricked by the needle; this contraction was therefore not communicated to it by the moving needle, but was generated, and therefore an original motion.

In all communicated motion, by which two bodies at a distance are brought near to one another, there must subsist some other matter, by which they may be drawn, or forced, nearer to one another; but in original motion, it is not at all necessary that any other matter should exist at all. Two particles, placed at as great a distance from one another as the sun is from the earth, as has been already observed, although at perfect rest, would begin to move nearer one another, by the attraction of gravitation, if all other matter whatever were annihilated.

Most authors who have treated on muscular motion have supposed, that it was a communicated motion; and that it was

produced by something passing by the nerves, from the brain to the moving part. Three doctrines have been set forth; one, that there is a fluid passing along the nerves; a second, that there is a vibration; and a third, that the nerves are surrounded with something like electric matter, in which motion runs from the brain to the moving parts. Those who have considered this subject must be tired of the arguments which have been brought to refute each of these; for no argument from fact has been employed to prove any one of them: I shall therefore leave them as mere chimeras of the brain. I have taken notice, that it is not requisite for any motion to pass between two bodies, exciting in each other an original motion, through or by any other matter: I have also shewn, that muscular motion is an original motion: it follows, that it is not necessary for any motion, or communication, to pass through any other matter, in order to bring the muscular fibres into action.

One case of muscular motion is, when a stimulus is applied to some part of the body, and a muscle at a distance immediately contracts. It has been supposed in this case, that some influence was communicated to the nerve of the part where the stimulus was applied, and through it to the brain, and from the brain through the nerves of the contracting muscle. Granting, for a little, that some motion may pass along the nerves, and therefore that the end of the nerve, where the application was made, may be the part in which the original motion began, the stimulus frequently does not touch the end of the nerve; for if vapour of volatile alkali be applied to the nostrils, an universal glow of heat, and increased circulation, will constantly take place; but the vapour of the volatile alkali could not touch the nerves of the nostrils, the membrane
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being constantly covered with mucus, which the vapour could not penetrate without dissolving it, which it had not time to do, and, if it had, would have united with it, so as to form a soap, void of any stimulating power.

If, therefore, the original motion began in the end of the nerves of the nostril, it must be excited by a substance at a distance from the end of that nerve, without any communication of motion between the stimulus, that is, application producing the motion, and the end of the nerve in which it is excited; therefore, on any supposition, a stimulus is capable of exciting a motion, in a part at a distance, without any communication of motion; and it is therefore not necessary, that the nerves should be at all employed in the motions of the body excited by a stimulus, as it can act at a distance without their intervening. Further, that the nerves are not employed in the motions excited by stimuli, is evident from this experiment: take the heart out of a living animal, cut all the nerves off as close as possible, lay it in nearly the heat of the body of the animal, it will continue to contract for some time. As soon as it has ceased contracting, prick a fibre in one of the ventricles; both ventricles, and all their fibres, will contract instantly, although there be now no communication by the nerves, between many of the contracting fibres, and the fibre stimulated. It might be suspected, that the motion of the fibre stimulated might affect the others: in this case the contractions would be progressive; but, on the contrary, the whole contract at once.

I cannot help bringing another instance, where stimuli produce action in parts at a distance, without any communication of motion by the nerves. When infusion of cantharides is applied to the skin, as we say vulgarly, it is not applied immediately to the skin; but in the first instance to the mucous

and sebaceous matter, which every where covers the scarf skin; under this lies the scarf skin, which the infusion can hardly be conceived to come at; if it did, the scarf skin we know is perfectly impenetrable to such a fluid; it can therefore never touch the skin, in which it excites inflammation, and on which it therefore acts at a distance, and excites motion, which no one can suspect to come through the nerves: nor is there any motion through the mucus and scarf skin, of any other kind than would arise if an infusion of any other infect had been applied, which had no power of exciting inflammation.

From what has been said we may conclude, that when a stimulus has been applied so as to excite motion in a distant part, no motion whatever takes place in the nerves, or is communicated by them from the part to which the stimulus is applied to the moving part.

I need not draw your attention to another proposition, *viz.* that when a stimulus is applied to a distant part, so as to produce motion, it often happens, that the stimulating matter is not carried by the blood-vessels, or otherwise, to the moving part. This proposition has often been demonstrated, and is well known.

All the original power exerted by any of the moving parts consists in a power of particles coming nearer one another; for every muscle or fibre becomes shorter when it acts; or, in other words, contracts; and every other moving part in like manner contracts when in action. It is true, that there are many contrivances to make the contraction have great effect in producing motion, force being never spared for conveniency, as my friend Mr. HUNTER has, I believe, already set forth to my learned audience: but, nevertheless, it is clear from every
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experiment made on the subject, that all motion arises from particles coming near one another in some direction. It would be superfluous for me to point out these experiments; I shall mention one only, and an obvious one. Lay bare a muscle, and prick any of its fibres, it immediately becomes shorter.

The original power of coming nearer to one another of two or more particles of matter, has been called attraction. There have been several original powers of coming nearer one another of particles of matter, which have been considered as different attractions, such as the attraction of gravitation, of magnetism, of electricity, &c.; all of which this Society are too much masters off, for me to enter into any disquisition with regard to them.

The attraction which is my present object, I call the attraction of life. This attraction is either of two species, or is exerted variously; for all the moving parts have their particles nearer one another in the living than in the dead body. The proof of this is as necessary as it is obvious. I must, therefore, take up a small portion of your time in pointing it out. Take the body of any animal, when the life is entirely gone from it, and the effects of it are entirely lost, but before any putrefaction, or any change in its chemical qualities, has taken place; and lay bare, and dissect out, any muscle, especially one which has long fibres, and no middle tendon, such as the *sartorius*, for example, and afterwards lay it in its place, leaving it of the length it naturally takes; it will reach farther than from its origin to its insertion; but lay bare, and dissect out, the same muscle in the living body, and it will always be shorter than from its origin to its insertion. If it should be said, that the dissection stimulated the muscle, and brought it into action, let it not be dissected out, but its tendon cut through, as the

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Tendo Achillis, for instance, the same thing will happen. And we now are all convinced, from various experiments, that a tendon in a sound state is not capable of being stimulated by being wounded, cut through, or broken.

I apprehend, then, that we may conclude, that all the moving parts are constantly contracted, that is, their particles are nearer one another when the body is alive, than when dead, and totally left to their elasticity. This species of action I call the tone. The second species, or variety, which occurs in the attraction of life, is when a moving part, for a short time, has its particles brought nearer one another than they are from their tone, and which very rarely continues for many seconds of time without intermediate relaxation. I call it their action; when it does continue for a longer time, it is called spasm; which, however, is so vague a term, that I could with totally to reject it, at least to confine it only to this sense, *viz.* a greater contraction, or coming nearer one another of the particles, of a moving part, than that which would happen from their tone, remaining without any intermediate relaxation.

I for the present do not mean to say any thing farther with regard to the tone, or spasm of parts; but only to call to your consideration the action, as excited by applications to some part of the body at a distance from the moving part. I have already rejected all communication by the application, or stimulus, being carried by the blood-vessels, or any other way whatever, to the part. I have also rejected any motion, or communication of any kind whatever by the brain and nerves to the part. I conceive, that when any stimulus or application whatever is made in any part, so as to produce any action in a distant part, that that medicine or application, without having any operation whatever on the intermediate parts, gives a
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power to the particles of the moving part of greater attraction. I shall illustrate this idea by supposing, that there is a machine moving by various powers, either original or communicated; and that in this machine there are two magnets, which by their attractive power have come to a given distance from one another, but have been prevented from coming nearer by some power endeavouring to draw them back. A much stronger magnet applied to a part of the machine, in a certain manner, so as not to touch either of the two already there, nor to affect any other part, may increase their power of attraction, so as to make them overcome the resistance, and come nearer one another*.

In the same manner, I apprehend, that an application made to the skin of the abdomen may, and often does, occasion the action of the intestines to take place, without any effect whatever on the intermediate parts; but that it simply excites the attraction of the particles of the moving parts of the intestines; certainly a part of the matter through which the influence is to pass, *viz.*, the mucus and scarf skin, is actually inanimate matter.

In certain cases of original motion, there is attraction, or the coming nearer of particles only. In others, there is not only attraction, but opposite repulsion; the cases of which are unnecessary to enumerate to this Society. In the attraction of life there is no opposite repulsion; all the motions of the body are produced entirely by the force of particles coming nearer one another. When this force diminishes, or the action goes off, and leaves the part entirely to its tone, the particles of the moving part are by no means repulsed from one another, but

* I do not mean to insinuate, in the smallest degree, that the powers of the body at all depend on, or have any thing to do with, magnetism.

are left to be drawn asunder by their elasticity, weight, or the weight of the surrounding parts, or any other accidental power: but, nevertheless, there are applications which may be made to distant parts of the body, which may, and do, take off the attraction which occasions the action of the moving part; and all those reasonings which I have already applied to applications which excite action, and which are called stimuli, are equally applicable to those applications which make action cease, and which we call sedatives.

The great ground on which I have attempted to make these observations, is the foundation of certain maxims in the practice of medicine, which I shall now proceed to sketch out to the Society, whose institution, to me, has always seemed to include the philosophy, but not the actual practice, of medicine.

Medicine is a science of long cultivation in that channel in which all the sciences have flowed, and had early attained great perfection, I believe, from the testimony of various writers of antiquity, and other circumstances, which I pass over as well known to many of this learned body, and too foreign a digression from our present subject: for although CELSUS observes well, that there could be no physicians among the Greeks at the time of the Trojan war, inasmuch as HOMER never mentions one medicine, but only application to the Gods for the cure of fevers, and other internal diseases; yet the Egyptians, from whom the Greeks received a great part of their knowledge in all science, as well as in medicine, had certainly not only regular physicians for internal diseases, but likewise stone-cutters, oculists, aurists, &c. long before the Trojan war; and HIPPOCRATES, by his own testimony, took much of his knowledge from what he calls the ancients. In the progress, therefore, of the science

science of medicine, it came into my mind to enquire how far, and on what ground, the modern increase of science in anatomy, chemistry, mathematics, &c. had forwarded the knowledge of medicine. In the first place, it is well known to my learned Audience, that medicine was in the hands of Greek physicians from the time of HIPPOCRATES, or rather from the destruction of the Egyptian monarchy by CAMBYSES, down to the time of the Crusades; in all this time there was hardly a dissection of the human body, from an opinion about *manes*; but when it came into Europe again, where this opinion remained indeed, but in a much less degree, anatomy began again to flourish; and by other means all the other sciences shone forth with a greater lustre than they had ever done in any period handed down to us by history of any nation. It was obvious therefore to conceive, that the knowledge of the structure of the body, and the investigation of the powers of matter, made in a more accurate manner, and on a more extensive scale, would elucidate the doctrine of the human body, and its diseases, and their treatment, in a new and more perfect manner: to this opinion I mean now to apply the reasoning I have before laid down.

In the structure and physiology of the body, two great discoveries have been made by the moderns; the circulation of the blood; and the lymphatics, and absorption of the lymph. These at once overthrow the ideas of the ancients with regard to most of the functions of the interior parts of the body; which was now conceived by many to be an hydraulic machine, and subject to all those disorders which were incidental to such a machine; and particularly, from various fluids flowing with great rapidity, through tubes, many of them of infinite fineness, that stoppages must often take place, which

were to be removed by dissolving out the obstructing matter; that the blood was mixed so perfectly through all the body, and so constantly, that the same blood must be taken away, whatever blood-vessel was opened; and when we contemplate the numerous openings and communications of the vessels with one another, that blood flowing out of any one will empty them all equally, and that, therefore, it can be of no consequence from what part of the body blood is evacuated. In a pleurisy, for instance, where can be the difference, whether blood be taken from the right or left arm, or from the vessels of the skin of the breast? But there is a difference, and a great one too; since taking a much less quantity of blood from the skin of the breast, is actually known, in certain cases, from experience, to cure a pleurisy, than would have had that effect if taken from the vessels in the arm, and will even carry off the disease, when it could not be carried off at all by evacuation from the arm: yet it is undoubtedly the very same blood in all its qualities; and in both cases the vessels of the pleura are equally emptied. The act of flowing out of the blood from the vessels of the skin of the breast then has an immediate action on the action of the moving parts in the pleura, and carries off the inflammation independent of the circulation, or any of its laws; and so far has the knowledge of the circulation been of any advantage in this case, that it had nearly thrown out topical bleeding in inflammation, which is one of our most powerful remedies in the disease. In like manner, when the moving fibres of the stomach do not contract, so as to expel any vapour that may get into it, a spice applied to the skin over the stomach will, in many cases, occasion these fibres to contract. Now it is well known from anatomy, that there is no communication between the skin of the abdomen
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and the stomach; and if the spice were to act by touching these fibres, it would be the same, whether it was applied to the skin over the stomach, or to the skin of the arm; for in both cases it must be absorbed by the lymphatics, and carried to the left side of the heart, and there and in the lungs be blended universally with the whole blood, and carried by the arteries to the moving fibres of the stomach. Nay more, that it would be equal, whether it was applied to the inner surface of the stomach itself, or to the external skin, or any other membrane, of any other cavity: for the stomach is covered with mucus, and lined with a membrane which is perfectly impervious, and totally prevents any thing contained in the stomach from being any way applied to the moving fibres; it must in this case, therefore, be likewise taken up by the lymphatics, or lacteals, and carried to the heart before it could touch the moving fibres of the stomach. The maxim then, arising from our knowledge of the lymphatics, would be, that it was of no consequence where we applied a spice in cases of flatulency; which is not true. By similar reasons it might be easily shewn, were it not for tiring my learned Audience, that all the knowledge of the properties of the fluids, which has been acquired by modern and accurate experiments, hardly contributes any thing to the knowledge of applying medicines for the cure of diseases; and that the study of the laws of the attraction of life, or what has been called muscular motion, is of considerable importance.

One more observation I have only to make, *viz.* that all original motions are by their nature perfectly unintelligible as to their cause; who can tell the cause of gravity, chemical attraction, &c.? and so undoubtedly the attraction of life, in its cause can never be investigated, being, like all other attrac-

tion, a power which two or more particles of matter have of coming nearer one another. But although the study of causes of original powers be totally absurd and futile, yet the laws of their action are capable of investigation by experiment, and applicable to the evolving much useful knowledge. Need I remind this Society, that the investigation of the laws of gravitation, by Sir ISAAC NEWTON, has rendered it immortal? The investigation of the laws of the attraction of life has also been greatly forwarded by one of its present members; but it is an investigation which will probably require ages to render perfect.

